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GEOLOGIC RANGE OF MIOCENE INVERTEBRATE FOSSILS OF CALIFORNIA

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Faunal Zones in the Miocene of California.

When Conrad described the Tertiary fossils of California in the Reports of the Pacific Railroad Survey, he assigned some species to the Miocene on account of a vague resemblance to Miocene species from Virginia and Maryland; but he had no positive criterion for distinguishing the various faunas. When, in 1868, Gabb wrote his monograph on the Tertiary of California, he, too, had little opportunity of distinguishing the separate faunas that make up the beautiful succession, as we know it, on the West Coast. Where the rock beds were much disturbed and hardened, he called them Miocene; and where they were little disturbed, and not lithified to any extent, he called them Pliocene. This criterion was usually right, but not always; for there are Miocene beds in California that are unconsolidated, and Pliocene beds that are turned up on edge and hardened into real rocks. In fact, the principal disturbance in the Tertiary beds of the Coast Ranges came in the mountain-making epoch at the end of Monterey, in the middle Miocene time, and, after this, several thousand feet of sandstones were laid down still containing Miocene fossils in abundance.

Later writers—Fairbanks, F. M. Anderson, Merriam, Lawson, and Arnold—have introduced a much more elaborate classification of the Neocene of California, and a large number of formation-names. But these so-called formations, however useful they may be for areal mapping and for economic geology, do not always correspond to the faunal divisions. Some of them are merely different facies of the same thing. The formations have been subdivided much more minutely than the faunas warrant.

Instead of the numerous subdivisions recognized by most stratigraphers, there are, in fact, only two major faunal units in the Miocene of California: a lower, including all the faunas up through the Monterey; and an upper, including the San Pablo, Santa Margarita, and Etchegoin faunas. The division line between them corresponds to the period of orogenic activity that came on at the end of the Monterey epoch. This marks not only a great change in the physiography of the West

Coast, but also the extinction of many of the older Miocene types, and the introduction of new forms, many of which have survived until the present time. This brings us back almost to the standpoint of Lawson and Merriam, who have proposed to call all the lower Miocene "Monterey," and all the upper Miocene "San Pablo."

The beds containing the Vaqueros, Temblor, and Monterey faunas were uplifted and somewhat hardened in the Coast Range uplift; and on the eroded flanks of this range were laid down the younger Miocene strata containing the Santa Margarita, San Pablo, and Etchegoin faunas. They too have been upturned by later disturbances, but not hardened to such a degree as were the older beds.

The fossils in these later Miocene beds not only have a much more recent appearance than those of the lower Miocene, but also the number of species still living is much greater among them. The number of these living species increases gradually as the top of the Miocene is approached, and the faunas grade over imperceptibly into the Pliocene. There is no natural boundary between Miocene and Pliocene in California, and the line is drawn between the Etchegoin and Purisima as a matter of convenience. In fact the two faunas overlap; and the formations may well do so. The Etchegoin has been called the Pliocene by F. M. Anderson, and upper Miocene by Arnold. The overlying Purisima has been called transitional by Ashley, Pliocene by Arnold, and upper Miocene by Dall. And since all these writers had good reasons for their opinions, it is safe to conclude that the line between Miocene and Pliocene should be drawn somewhere near the boundary line between the two formations.

One of the most striking characteristics of the Tertiary of California is the orderly advance toward modern life, with a constantly increasing number of modern species, and a constantly increasing number of species closely allied to recent forms. Step by step each succeeding fauna becomes more like the present life of the California coast than the preceding. This gradual change finds its explanation in the physiography of the region. All through the Tertiary the coast line of California was nearly the same as at present; for while the orogenic

disturbances during that age have been profound and far-reaching, they were longitudinal. There was here, as elsewhere in the northern hemisphere, a gradual drop from the subtropical warmth of the Eocene to the cool climate of the Pliocene, the chill of the Glacial Epoch, and then a fluctuating rise to the genial climate of the present. This has been recorded in the successive marine faunas, but the changes were so gradual that during the Neocene there was no catastrophic destruction of the inhabitants of the sea. From each geologic formation many species live on into the next. It would have delighted Lyell to see such a complete illustration of the principle he adopted for the subdivision of the Tertiary, for here we have a gradation from the Eocene with no living species, through the Miocene and Pliocene with gradually increasing number of modern forms, the Quaternary with about 90 per cent of recent species, to the present, where in the same region, out of a marine fauna of somewhere near a thousand species, over four hundred extend back into the Quaternary, and nearly a hundred extend back into the Tertiary.

TABLE OF MIOCENE FAUNAS OF CALIFORNIA.

MIOCENE	UPPER	ETCHEGOIN fauna, of the Coalinga region, of the Salinas and the San Benito valleys.
		SAN PABLO-SANTA MARGARITA faunas, of the Mt. Diablo region, Salinas valley, and the Coalinga region.
	LOWER	MONTEREY-TEMBLOR faunas, of the Contra Costa hills, Mt. Hamilton Range, Black Mountain, Santa Lucia Range, Coalinga region, Bakersfield region, Santa Ynez and Santa Monica mountains, and Santa Ana Range.
		VAQUEROS fauna, of the Santa Lucia Range, Black Mountain, the Santa Monica and Santa Ynez mountains.

As shown in the table, there are only two major faunal divisions of the Miocene: a lower, including the Vaqueros and the Monterey-Temblor faunas; and an upper, including the San Pablo-Santa Margarita and the Etchegoin faunas.

The entire Miocene fauna consists of about 300 species described, and of these about 220 are confined to the Miocene.

The entire lower Miocene, as known as present, consists of about 173 species, of which 116 are confined to lower Miocene, 25 range into upper Miocene; 11 range into Pliocene; 1 ranges

into Quaternary; and 20 persist into the Recent fauna. The percentage of Recent species in the lower Miocene fauna taken as a whole is 11 per cent.

The Vaqueros fauna consists of 56 species, of which 10 are confined to the Vaqueros, or to this and the San Lorenzo Oligocene faunas; 25 range into the Monterey-Temblor faunas; 10 range into upper Miocene; 3 into Pliocene; 1 into Quaternary; and 6 range into the Recent fauna, giving 10 per cent of living species.

The Monterey-Temblor faunas contain a total of about 154 species, of which 25 range up from Vaqueros; about 70 are confined to Monterey-Temblor; 26 range into upper Miocene; 11 into Pliocene; 1 ranges into Quaternary; and 20 persist into the Recent fauna, giving 13 per cent of Recent species.

The following characteristic species are confined to the Vaqueros fauna:

Modiolus inezanus Arnold
Pecten magnolia Conrad
Pecten vanvlecki Arnold
Pecten vaughani Arnold
Turritella inezana Conrad
Turritella inezana var. *sespeensis* Arnold
Purpura vaquerosensis Arnold
Natica inezana Conrad
Scutella fairbanksi Arnold
Terebratalia kennedyi Arnold

This lowest horizon of the Miocene has been called by Merriam[1] the zone of *Turritella hoffmanni* (=*Turritella inezana*); it may eventually be found to be the inshore equivalent of the deep-water San Lorenzo Oligocene, with which it has a few species in common. Of this fauna only six species are known to have persisted to the present, namely, *Terebratalia occidentalis, Balanus concavus, Hinnites giganteus, Macoma nasuta, Phacoides richthofeni,* and *Psammobia edentula;* and of these *Macoma nasuta* appeared in the San Lorenzo Oligocene.

The following characteristic species are confined to the Vaqueros and Monterey-Temblor faunas:

Arca montereyana Osmont
Cardium vaquerosense Arnold
Chione conradiana Anderson
Chione mathewsoni Gabb
Dosinia conradi Gabb
Dosinia mathewsoni Gabb
Glycimeris branneri Arnold
Pecten branneri Arnold
Pecten lompocensis Arnold
Pecten miguelensis Arnold
Pecten nevadanus Conrad
Pecten peckhami Gabb
Pecten perrini Arnold
Pecten sanctaecruzensis Arnold
Pecten sespeensis Arnold
Agasoma barkerianum Cooper
Agasoma gravidum Gabb
Cuma biplicata Gabb
Trochita costellata Gabb

[1] Bull. Dept. Geol. Univ. Calif., vol. 3 (1904), p. 380.

The following characteristic species are confined to the Monterey-Temblor fauna:

Scutella breweriana Remond
Scutella merriami Anderson
Corbicula dumblei Anderson
Glycimeris barbarensis Conrad
Pecten hamlini Arnold
Pecten propatulus Conrad
Tellina congesta Conrad
Yoldia impressa Conrad
Yoldia oregona Shumard
Agasoma santacruzanum Arnold
Bathytoma keepi Arnold
Bullia anglonana Anderson
Cancellaria condoni Anderson
Conus hayesi Arnold
Conus owenianus Anderson
Ficus kernianus Cooper
Ficus nodiferus Gabb
Ficus pyriformis Gabb
Ficus stanfordensis Arnold
Oliva californica Anderson
Terebra cooperi Anderson
Trophon gabbianus Anderson
Turritella ocoyana Conrad
Turritella variata Conrad

In addition to the six species enumerated under the Vaqueros, the following species persist from the Monterey-Temblor fauna into the present:

Cardium quadrigenarium Conrad
Dosinia ponderosa Gabb
Leda taphria Dall
Macoma calcarea Gmelin
Macoma secta Conrad
Mactra catilliformis Conrad
Metis alta Conrad
Panopaea generosa Gould
Phacoides annulatus Reeve
Saxidomus nuttalli Conrad
Solen sicarius Gould
Tellina idae Dall
Lunatia lewisii Gould
Olivella pedroana Conrad

The entire upper Miocene fauna consists of about 182 species known at present. Of these 26 range up from lower Miocene, and become extinct in the San Pablo-Santa Margarita and Etchegoin faunas; about 77 are confined to the upper Miocene; 26 range into Pliocene, and become extinct in the Purisima or San Diego horizon; 2 range into Quaternary; and 50 persist into the Recent fauna.

The lower division of the upper Miocene consists of the San Pablo-Santa Margarita-Jacalitos faunas, which are a unit, or nearly so—the Jacalitos being merely the upper division of the Santa Margarita, and both together being the approximate equivalent of San Pablo. The aggregate fauna of this division amounts to 117 species, of which 38 are still living, giving 32 per cent of Recent forms.

In the Etchegoin fauna there are known 111 species, with 20 additional that existed both before and after that time, making 131 species. Of these 51 are still living, giving 38 per cent of Recent species in the Etchegoin fauna.

The following common and characteristic species range up from the lower Miocene, and become extinct in the San Pablo-Santa Margarita fauna:

Arca microdonta Conrad
Arca obispoana Conrad
Chione temblorensis Anderson
Cytherea diabloensis Anderson
Modiolus multiradiatus Gabb
Ostrea titan Conrad
Panopaea estrellana Conrad
Pecten andersoni Arnold
Pecten crassicardo Conrad
Pecten discus Conrad
Pecten estrellanus Conrad
Trophon carisaensis Anderson

The following characteristic species are confined to the San Pablo-Etchegoin fauna:

Pecten pabloensis Conrad
Astrodapsis antiselli Conrad
Astrodapsis tumidus Remond
Astrodapsis whitneyi Remond
Tamiosoma gregaria Conrad

The following species lived over from the lower Miocene, and became extinct in the Etchegoin:

Mulinia densata Conrad
Sigaretus scopulosus Conrad
Zirphea dentata Conrad
Trophon ponderosus Gabb

The following characteristic upper Miocene species became extinct in the Etchegoin:

Diplodonta harfordi Anderson
Diplodonta parilis Conrad
Glycimeris coalingaensis Arnold
Modiolus directus Dall
Mytilus coalingaensis Arnold
Ostrea vespertina Conrad
Ostrea atwoodi Gabb
Pecten coalingaensis Arnold
Placuanomia californica Arnold
Thais kettlemanensis Arnold
Turritella vanvlecki Arnold

The following characteristic species range up from lower Miocene, and become extinct in the lower Pliocene, Purisima-San Diego fauna:

Scutella gibbsi Gabb
Arca trilineata Conrad
Chione securis Shumard
Trochita filosa Gabb
Mactra albaria Conrad
Marcia oregonensis Conrad
Phacoides sanctaecrucis Arnold
Thracia trapezoidea Conrad
Venus pertenuis Gabb
Chione staleyi Gabb
Trochita inornata Gabb

The following characteristic upper Miocene species range over into lower Pliocene, and become extinct in the Purisima-San Diego fauna:

Astrodapsis perrini Weaver
Scutella gibbsi Gabb var. *ashleyi* Arnold
Arca canalis Conrad
Cryptomya ovalis Conrad
Cardium coosense Dall
Cardium meekanum Gabb
Macoma astori Dall
Ostrea veatchi Gabb
Pecten cerrosensis Gabb
Pecten cerrosensis var. *mendenhalli* Arnold
Pecten nutteri Arnold
Pecten oweni Arnold
Pecten wattsi Arnold
Schizothoerus pajaroanus Conrad
Chrysodomus imperialis Dall
Chrysodomus portolaensis Arnold
Miopleioma oregonensis Dall

Crepidula princeps Conrad persists from lower Miocene into Quaternary, and *Pisania fortis* Carpenter persists from upper Miocene into Quaternary before becoming extinct.

Throughout the Miocene, into the Pliocene, and up to the present, little evolution of forms is seen. Species appear with all their characteristics distinctly marked, run their course, and disappear from our ken, without any appreciable change. The geologist, looking over collections from the lowest Miocene to the Recent fauna, rarely sees the evolution of marine invertebrates. He sees only the sudden appearance of forms, and equally sudden disappearance of the same, without knowing whence they came, or how they disappeared.

This could be used as an argument for saltatory or spasmodic evolution. But it could be used equally well as an argument for special creation. In fact, the paleontologist does not see here any spasmodic evolution; he sees only sudden appearance. The species appear before us in the rocks, without any previous record or credentials as to their history—presumably as immigrants, having been evolved somewhere else. They live on a while, and disappear a few at a time.

In the few cases where there is even a suggestion of evolution of species, this is not spasmodic, but slow and regular. In the Venus shells there is a probable genetic series, from *Chione temblorensis* in the lower Miocene, through *Chione securis* in the middle and upper part of the Miocene, to the group of *Chione succincta* of the Pliocene, Quaternary, and Recent faunas.

An equally good genetic series is seen in the development of *Pecten andersoni* of the lower Miocene into *Pecten discus* and *Pecten pabloensis* of the upper Miocene.

Another probable genetic series is that of the group of "Janira"; namely, *Pecten sanctaecruzensis* of the lower Miocene, *Pecten bellus* of the Pliocene, and *Pecten excavatus* of the Quaternary and Recent faunas. In this case there was a gradual retreat southward as the climate grew cooler, and the modern representatives are almost entirely confined to warmer waters. In addition to these, nearly fifty other species in the Recent fauna can be traced somewhat doubtfully into Miocene ancestors.

The tables of the occurrence and range of the Miocene species of California are based on a critical study of all the literature, and a critical examination of extensive collections from all the Miocene localities in California. Of course the list is not complete, for there are many undescribed species in the collections of the U. S. National Museum, of the University of California, of the California Academy of Sciences, and of Stanford University. Also some species that are now put together may not be synonyms, and very certainly some that are now treated separately will eventually be merged.

Further examination of better material will probably show that some of the Miocene species, now considered as identical with Recent forms, are different. And further collection will probably bring to light more Recent species in the Miocene faunas. But none of this will change materially the figures and percentages given. The numbers are too large, and the collections already made are too extensive for that to be the case.

It is hoped that this list will be of use to students of Californian stratigraphy, for whom it was prepared. Each one can do something towards completing it, by adding new species as they are described, checking the occurrence of old species, correcting the synonymy, and inserting names that have been omitted.

In the check-list the Temblor and Monterey faunas are entered separately as a matter of record, although they are certainly synchronous. The lower Pliocene faunas are merged under the name *San Diego-Purisima* for convenience of reference; and the upper Pliocene is recorded under the name *Santa Barbara,* because it is by no means certain that the name *Merced,* which has been used for the upper Pliocene, is applicable in southern California. The name *Fernando,* which has been extensively used in listing the faunas of southern California, is not applicable, for it has included faunas from lowest Pliocene to middle Quaternary in age.

CHECK-LIST OF MIOCENE INVERTEBRATES OF CALIFORNIA

GENERA AND SPECIES	OLIGOCENE	MIOCENE					PLIOCENE		QUATERNARY	RECENT
		Lower			Upper		Lower	Upper		
	San Lorenzo	Vaqueros	Temblor	Monterey	San Pablo-Sta. Margarita	Etchegoin	San Diego-Purisima	Sta. Barbara	San Pedro	
Astrangia coalingensis Vaughan						×				
Favia merriami Vaughan						×				
Stephanocoenia fairbanksi Vaughan						×				
Amphiura sanctaecrucis Arnold					×					
Asterias remondi Gabb					×					
Astrodapsis antiselli Conrad					×					
Astrodapsis antiselli, var. *arnoldi* Pack					×					
Astrodapsis jacalitosanus Arnold					×					
Astrodapsis fernandoensis Pack				×						
Astrodapsis tumidus Remond					×					
Astrodapsis whitneyi Remond					×					
Scutaster andersoni Pack					×					
Scutella fairbanksi Arnold		×								
Scutella merriami Anderson			×							
Scutella perrini Weaver						×	×			
Scutella norrisi Pack		×								
Scutella breweriana Remond				×						
Scutella gibbsi Remond				×	×	×	×			
Scutella gibbsi, var. *ashleyi* Arnold						×	×			
Clypeaster bowersi Weaver						×				
Clypeaster gabbi Remond					×					
Linthia californica Weaver			×							
Terebratalia kennedyi Dall		×								
Terebratalia occidentalis Dall		×			×	×	×			×
Terebratalia Smithi Arnold						×	×	×		
Discinisca oregonensis Dall			×	×	×					
Balanus concavus Brown		×			×	×	×	×	×	×
Balanus estrellanus Conrad					×					
Tamiosoma gregaria Conrad				?	×					
Anomia subcostata Conrad						×				
Arca canalis Conrad					×		×	×		
Arca microdonta Conrad		×	×	×	×					
Arca montereyana Osmont			×	×						
Arca obispoana Conrad			×	×	×					
Arca osmonti Dall			×							
Arca trilineata Conrad			×		×	×	×	×		
Arca schizotoma Dall						×	×	×		
Arcopagia unda Conrad					×					
Cardium coosense Dall						×	×			
Cardium meekanum Gabb					×	×	×			

Check-List of Miocene Invertebrates of California—*Continued.*

Genera and Species	Oligocene	Miocene						Pliocene		Quaternary	Recent
		Lower			Upper			Lower	Upper		
	San Lorenzo	Vaqueros	Temblor	Monterey	San Pablo-Sta. Margarita	Etchegoin		San Diego-Purisima	Sta. Barbara	San Pedro	
Cardium quadrigenarium Conrad			×	×	×	×			×	×	×
Cardium vaquerosense Arnold		×	×								
Chama pellucida Sowerby						×			×	×	×
Chione conradiana Anderson		×	×								
Chione mathewsoni Gabb		×	×	×							
Chione securis Shumard			×	×	×	×		×			
Chione staleyi Gabb				×	×	×		×			
Chione temblorensis Anderson		×	×	×	×						
Clidiophora punctata Conrad					×	×		×		×	×
Corbicula dumblei Anderson			×								
Cryptomya ovalis Conrad					×	×		×			
Cryptomya quadrata Arnold						×		×			
Cumingia californica Conrad						×		×	×	×	×
Cyrena californica Gabb					×						
Cytherea diabloensis Anderson			×	?	×						
Diplodonta harfordi Anderson					×	×					
Diplodonta parilis Conrad					×	×					
Dosinia jacalitosana Arnold					×						
Dosinia ? longula Conrad					?						
Dosinia mathewsoni Gabb		×	×	×							
Dosinia montana Conrad					?						
Dosinia ponderosa Gabb			×	×	×	×		×		×	×
Dosinia subobliqua Conrad					?						
Dosinia conradi Gabb		×									
Gari alata Gabb					×						
Glycimeris barbarensis Conrad			×								
Glycimeris branneri Arnold		×	×								
Glycimeris coalingaensis Arnold					×	×					
Glycimeris septentrionalis Midd						×				×	×
Hemimactra lenticularis Gabb			×								
Hinnites crassus Conrad					×						
Hinnites giganteus Gray		×	×		×	×				×	×
Lucina estrellana Conrad					×						
Macoma calcarea Gmelin			×	×		×		×	×	×	×
Macoma inquinata Deshayes				×		×		×	×	×	×
Macoma astori Dall						×		×			
Macoma jacalitosana Arnold					×						
Macoma nasuta Conrad	×	×	×	×	×	×		×	×	×	×
Macoma piercei Arnold			×								
Macoma secta Conrad			×		×	×		×		×	×
Macoma vanvlecki Arnold				×	×						

CHECK-LIST OF MIOCENE INVERTEBRATES OF CALIFORNIA—*Continued.*

GENERA AND SPECIES	OLIGOCENE	MIOCENE						PLIOCENE		QUATERNARY	RECENT
		Lower			Upper			Lower	Upper		
	San Lorenzo	Vaqueros	Temblor	Monterey	San Pablo-Sta. Margarita	Etchegoin		San Diego-Purisima	Sta. Barbara	San Pedro	
Macoma ocoyana Conrad			×								
Mactra albaria Conrad			×	×	×			×			
Mactra catilliformis Conrad			×	×				×		×	×
Mactra coalingaensis Arnold						×					
Mactra montereyana Arnold				×							
Marcia oregonensis Conrad	×		×		×			×			
Meretrix uniomeris Conrad						?					
Meretrix traski Conrad				×							
Meretrix decisa Conrad			×								
Metis alta Conrad			×		×	×		×		×	×
Modiolus capax Conrad					×			×			×
Modiolus directus Dall						×					
Modiolus multiradiatus Gabb				×	×						
Modiolus rectus Conrad					×	×		×	×	×	×
Modiolus ynezanus Arnold	×	×									
Monia macroschisma Deshayes					×						×
Mulinia densata Conrad			×		×	×					
Mulinia, var. *minor* Arnold			×								
Mya japonica Jay						×					×
Mytilus coalingaensis Arnold					×	×					
Mytilus inezensis Conrad		?									
Mytilus mathewsoni Gabb		×	×	×	×						
Mytilus mathewsoni, var. *expansa* Arnold		×	×								
Nucula castrensis Hinds					×	×		×	×	×	×
Nucula conradi Meek			×								
Ostrea atwoodi Gabb					×	×					
Ostrea bourgeoisi Gabb					×						
Ostrea eldridgei Arnold		×	×								
Ostrea heermanni Conrad						×					
Ostrea panzana Conrad					×						
Ostrea lurida Carpenter						×				×	×
Ostrea tayloriana Gabb			?								
Ostrea titan Conrad		×	×	×	×						
Ostrea veatchii Gabb						×		×			
Ostrea vespertina Conrad						×					
Ostrea vespertina, var. *sequens* Arnold						×					
Leda cahillensis Arnold			×								
Leda taphria Dall			×	×				×		×	×
Pandora scapha Gabb			×								

Check-List of Miocene Invertebrates of California—*Continued.*

Genera and Species	Oligocene	Miocene					Pliocene		Quaternary	Recent
		Lower			Upper		Lower	Upper		
	San Lorenzo	Vaqueros	Temblor	Monterey	San Pablo-Sta. Margarita	Etchegoin	San Diego-Purisima	Sta. Barbara	San Pedro	
Panopaea generosa Gould			×	×	×	×	×		×	×
Panopaea estrellana Conrad		×	×		×					
Paphia jacalitosana Arnold					×					
Paphia tenerrima Carpenter					×	×	×		×	×
Paphia staminea Carpenter					×		×		×	×
Paphia truncata Gabb					×					
Pecten andersoni Arnold			×	×	×					
Pecten branneri Arnold	×	×	×							
Pecten carrizoensis Arnold						×				
Pecten cerrosensis Gabb						×	×			
Pecten cerrosensis, var. *mendenhalli* Arnold						×				
Pecten coalingaensis Arnold						×				
Pecten crassicardo Conrad		×	×	×	×					
Pecten crassicardo, var. *hamiltoni* Arnold			×							
Pecten deserti Conrad						×				
Pecten discus Conrad				×	×					
Pecten eldridgei Arnold					×					
Pecten estrellanus Conrad		×	×		×					
Pecten estrellanus var. *catalinae* Arnold					×					
Pecten estrellanus var. *terminus* Arnold					×					
Pecten etchegoini Anderson						×				
Pecten hamlini Arnold			×							
Pecten hastatus Sowerby						×	×	×	×	×
Pecten keepi Arnold						×				
Pecten lompocensis Arnold		×	×							
Pecten magnolia Conrad		×								
Pecten miguelensis Arnold		×	×							
Pecten nevadanus Conrad		×	×							
Pecten nutteri Arnold						×	×			
Pecten oweni Arnold					×	×	×			
Pecten pabloensis Conrad					×					
Pecten peckhami Gabb		×		×						
Pecten perrini Arnold		×	×							
Pecten propatulus Conrad			×							
Pecten sanctaecruzensis Arnold	×	×	×							
Pecten sespeensis Arnold		×	×							
Pecten sespeensis, var. *Hydei* Arnold		×	×							
Pecten stanfordensis Arnold				×						

Check-List of Miocene Invertebrates of California—*Continued.*

Genera and Species	Oligocene	Miocene					Pliocene		Quaternary	
		Lower			Upper		Lower	Upper		
	San Lorenzo	Vaqueros	Temblor	Monterey	San Pablo-Sta. Margarita	Etchegoin	San Diego-Purisima	Sta. Barbara	San Pedro	Recent
Pecten vanvlecki Arnold		×								
Pecten vaughani Arnold		×								
Pecten veatchi Gabb						×				
Pecten wattsi Arnold						×	×			
Periploma sanctaecrucis Arnold				×						
Phacoides acutilineatus Conrad		×	×	×		×				
Phacoides annulatus Reeve				×	×	×	×	×	×	×
Phacoides richthofeni Gabb		×	×	×			×			×
Phacoides sanctaecrucis Arnold		×	×	×			×			
Pholadidea ovoidea Gould						×				×
Placuanomia californica Arnold					×	×				
Pinna alamedensis Yates			×		×					
Psammobia edentula Gabb		×	×				×		×	×
Saxidomus nuttalli Conrad			×		×	×	×	×	×	×
Saxidomus vaquerosensis Arnold			×							
Semele rubropicta Dall						×				×
Schizodesma abscissa Gabb					×					
Schizothoerus pajaroanus Conrad					×	×	×			
Septifer coalingaensis Arnold			×							
Siliqua nuttalli Conrad					×	×	×	×	×	×
Solen sicarius Gould			×	×	×		×			×
Tapes inezensis Conrad		?								
Tellina aragonia Dall					×					
Tellina congesta Conrad				×						
Tellina idae Dall			×					×	×	×
Tellina oregonensis Conrad			×							
Tivela inezana Conrad		×	×		×					
Thracia jacalitosana Arnold					×					
Thracia mactropsis Conrad				×						
Thracia trapezoidea Conrad			×			×	×			
Transenella californica Arnold						×				
Venus pertenuis Gabb		×	×		×		×			
Venericardia montereyana Arnold				×						
Venericardia ventricosa Gould						×	×	×	×	×
Yoldia cooperi Gabb					×		×		×	×
Yoldia impressa Conrad	×		×							
Yoldia oregona Shumard			×							
Yoldia submontereyensis Arnold			×							
Yoldia supramontereyensis Arnold				×						
Zirphea dentata Gabb			×		×					
Zirphea gabbi Tryon					×	×	×		×	×
Agasoma barkerianum Cooper		×	×	×						

Check-List of Miocene Invertebrates of California—*Continued.*

Genera and Species	Oligocene	Miocene						Pliocene		Quaternary	Recent
			Lower			Upper		Lower	Upper		
	San Lorenzo	Vaqueros	Temblor	Monterey	San Pablo-Sta. Margarita	Etchegoin	San Diego-Purisima	Sta. Barbara	San Pedro		
Agasoma gravidum Gabb		×	×								
Agasoma santacruzanum Arnold			×								
Agasoma sinuatum Gabb				×							
Ancillaria fishii Gabb			×								
Astyris richthofeni Gabb						×					
Bathytoma carpenteriana Gabb						×	×		×		×
Bathytoma carpenteriana, var. *fernandoensis* Arnold						×	×				
Bathytoma coalingaensis Arnold						×					
Bathytoma keepi Arnold			×								
Bathytoma piercei Arnold			×								
Bittium asperum Gabb					×			×	×		×
Bullia anglonana Anderson			×								
Calliostoma coalingaense Arnold						×					
Calliostoma kerri Arnold						×					
Cancellaria altispira Gabb				×							
Cancellaria andersoni Arnold			×								
Cancellaria condoni Anderson			×								
Cancellaria joaquinensis Anderson			×								
Cancellaria dalliana Anderson			×								
Cancellaria pacifica Anderson			×								
Cancellaria simplex Anderson			×								
Cancellaria tritonidea Gabb						×	×	×	×		
Cancellaria vespertina Anderson					×						
Cancellaria vetusta Gabb			×								
Cerithium topangensis Arnold			×								
Chrysodomus imperialis Dall					×	×	×				
Chrysodomus portolaensis Arnold					×	×	×				
Conus owenianus Anderson			×								
Conus hayesi Arnold			×								
Crepidula onyx Sowerby					×		×		×		×
Crepidula praerupta Conrad			×		×						
Crepidula princeps Conrad		×	×		×	×	×	×	×		
Cuma biplicata Gabb		×	×								
Cylichna petrosa Conrad				×							
Dentalium conradi Dall			×								
Ficus kernianus Cooper		×	×	×							
Ficus nodiferus Gabb			×	×							
Ficus ocoyanus Conrad			×								
Ficus pyriformis Gabb			×	×							
Ficus stanfordensis Arnold			×	×							
Fusus portolaensis Arnold						×	×				

CHECK-LIST OF MIOCENE INVERTEBRATES OF CALIFORNIA—*Continued.*

GENERA AND SPECIES	OLIGOCENE	MIOCENE					PLIOCENE		QUATERNARY	
		Lower			Upper		Lower	Upper		
	San Lorenzo	Vaqueros	Temblor	Monterey	San Pablo-Sta. Margarita	Etchegoin	San Diego-Purisima	Sta. Barbara	San Pedro	RECENT
Fusus stanfordensis Arnold			×	×		×				
Goniobasis kettlemanensis Arnold						×				
Hemifusus wilkeseanus Anderson			×							
Littorina mariana Arnold						×				
Littorina planaxis Phill					×					×
Littorina remondi Gabb					×					
Lunatia lewisii Gould				×	×	×	×	×	×	×
Macron merriami Arnold			×							
Margarita johnsoni Arnold					×					
Metula remondi Gabb			×							
Miopleionia oregonensis Dall						×	×			
Monoceros engonatum Conrad					×					×
Nassa arnoldi Anderson			×							
Nassa californiana Conrad					×	×	×		?	×
Nassa californiana, var. *coalingaensis* Arnold						×				
Natica geniculata Conrad			×							
Natica inezana Conrad		×								
Neptunea recurva Gabb					×					
Neverita callosa Gabb		×	×		?					
Neverita recluziana Petit					×	×	×	×	×	×
Ocinebra topangensis Arnold			×							
Ocinebra lurida Midd					×	×	×		×	×
Oliva californica Anderson			×							
Oliva futheyana Anderson			×							
Olivella biplicata Sowerby						×	×	×	×	×
Olivella pedroana Conrad			×		×	×		×	×	×
Pachypoma biangulata Gabb		×	×		×					
Pisania fortis, var. *angulata* Arnold						×				
Pleurotoma transmontana Conrad			×							
Purpura vaquerosensis Arnold		×								
Ranella mathewsoni Gabb			×							
Scaphander jugularis Conrad			×							
Sigaretus scopulosus Conrad	×		×			×				
Sigaretus perrini Arnold			×							
Terebra cooperi Anderson			×							
Thais canaliculata Ducl					×			×	×	×
Thais crispata Chem					×	×	×		×	×
Thais edmondi Arnold			×							
Thais etchegoinensis Arnold						×				
Thais kettlemanensis Arnold					×	×				
Trochita costellata Conrad		×	×	×						

Check-List of Miocene Invertebrates of California—*Continued.*

Genera and Species	Oligocene	Miocene					Pliocene		Quaternary	Recent
		Lower			Upper		Lower	Upper		
	San Lorenzo	Vaqueros	Temblor	Monterey	San Pablo-Sta. Margarita	Etchegoin	San Diego-Purisima	Sta. Barbara	San Pedro	
Trochita diegoana Conrad						?				
Trochita filosa Gabb			×		×		×			
Trochita inornata Gabb				×	×		×			
Trophon bartoni Arnold			×							
Trophon carisaensis Anderson				×	×					
Trophon coalingaensis Arnold						×				
Trophon gabbianus Anderson			×							
Trophon gabbianus, var. *cancellarioides* Arnold			×							
Trophon kernensis Anderson			×							
Trophon ponderosus Gabb				×	×	×				
Trophon stuarti Smith						×		×	×	×
Turbo topangensis Arnold			×							
Turritella inezana Conrad		×								
Turritella inezana, var. *sespeensis* Arnold		×								
Turritella ocoyana Conrad			×							
Turritella vanvlecki Arnold					×	×				
Turritella variata Conrad			×							
Vanikoro diegoana Conrad						?				
Triptera clavata Gabb			×							

Species Confined to the Lower Miocene—Vaqueros, Temblor, and Monterey Faunas

Genera and Species	San Lorenzo	Vaqueros	Temblor	Monterey
Linthia californica Weaver			×	
Astrodapsis fernandoensis Pack				×
Scutella fairbanksi Arnold		×		
Scutella merriami Anderson			×	
Scutella norrisi Pack		×		
Scutella breweriana Gabb				×
Terebratalia kennedyi Dall		×		

SPECIES CONFINED TO THE LOWER MIOCENE—*Continued*

GENERA AND SPECIES	San Lorenzo	Vaqueros	Temblor	Monterey
Arca montereyana Osmont			X	X
Arca obispoana Conrad			X	X
Arca osmonti Dall			X	
Cardium vaquerosense Arnold		X	X	
Chione conradiana Anderson		? X	X	
Chione mathewsoni Gabb			X	X
Corbicula dumblei Anderson			X	
Dosinia conradi Gabb		X		
Dosinia mathewsoni Gabb		X	X	X
Glycimeris barbarensis Conrad			X	
Glycimeris branneri Arnold		X	X	
Hemimactra lenticularis Gabb			X	
Leda cahillensis Arnold			X	
Macoma piercei Arnold			X	
Macoma ocoyana Conrad			X	
Mactra montereyana Arnold				X
Meretrix decisa Conrad			X	
Modiolus ynezanus Arnold	X	X		
Mytilus inezensis Conrad		X		
Mytilus mathewsoni Gabb, var. *expansa* Arnold		X	X	
Nucula conradi Meek			X	
Ostrea eldridgei Arnold		X	X	
Pandora scapha Gabb			X	
Periploma sanctaecrucis Arnold				X
Pecten branneri Arnold	X	X	X	
Pecten hamlini Arnold			X	
Pecten lompocensis Arnold		X	X	
Pecten magnolia Conrad		X		
Pecten nevadanus Conrad		X	X	
Pecten peckhami Gabb	X	X		X
Pecten perrini Arnold		X	X	
Pecten propatulus Conrad			X	
Pecten sanctaecruzensis Arnold	X		X	
Pecten sespeensis Arnold		X	X	
Pecten sespeensis, var. *hydei* Arnold		X	X	
Pecten stanfordensis Arnold				X
Pecten vanvlecki Arnold		X		
Pecten vaughani Arnold		X		
Saxidomus vaquerosensis Arnold			X	
Septifer coalingaensis Arnold			X	
Tapes inezensis Conrad		?		
Tellina congesta Conrad				X
Tellina oregonensis Conrad			X	
Yoldia impressa Conrad	X		X	
Yoldia oregona Shumard			X	
Yoldia submontereyensis Arnold			X	
Yoldia supramontereyensis Arnold				X
Agasoma barkerianum Cooper		X	X	X
Agasoma gravidum Gabb			X	
Agasoma santacruzanum Arnold			X	
Agasoma sinuatum Gabb				X

Species Confined to the Lower Miocene—*Continued*

Genera and Species	San Lorenzo	Vaqueros	Temblor	Monterey
Ancillaria fishii Gabb			X	
Bathytoma keepi Arnold			X	
Bathytoma piercei Arnold			X	
Bullia anglonana Anderson			X	
Cancellaria altispira Gabb				X
Cancellaria andersoni Arnold			X	
Cancellaria condoni Anderson			X	
Cancellaria dalliana Anderson			X	
Cancellaria joaquinensis Anderson			X	
Cancellaria pacifica Anderson			X	
Cancellaria simplex Anderson			X	
Cancellaria vetusta Gabb			X	
Cerithium topangensis Arnold			X	
Conus hayesi Arnold			X	
Conus owenianus Anderson			X	
Cuma biplicata Gabb		X	X	
Cylichna petrosa Conrad				X
Dentalium conradi Dall			X	
Ficus kernianus Cooper		X	X	X
Ficus nodiferus Gabb			X	X
Ficus ocoyanus Conrad			X	
Ficus pyriformis Gabb			X	X
Ficus stanfordensis Arnold			X	X
Fusus stanfordensis Arnold			X	X
Hemifusus wilkesanus Anderson			X	
Metula remondi Gabb			X	
Macron merriami Arnold			X	
Nassa arnoldi Anderson			X	
Natica geniculata Conrad			X	
Natica inezana Conrad		X		
Ocinebra topangensis Arnold			X	
Oliva californica Anderson			X	
Oliva futheyana Anderson			X	
Pleurotoma transmontana Conrad			X	
Pupura vaquerosensis Arnold		X		
Ranella mathewsoni Gabb			X	
Scaphander jugularis Conrad			X	
Sigaretus perrini Arnold			X	
Terebra cooperi Anderson			X	
Thais edmondi Arnold			X	
Trochita castellata Conrad		X	X	X
Trophon bartoni Arnold			X	
Trophon gabbianus Anderson			X	
Trophon gabbianus, var. *cancellarioides* Arnold			X	
Trophon kernensis Anderson			X	
Turbo topagensis Arnold			X	
Turritella inezana Conrad		X		
Turritella inezana, var. *sespeensis* Arnold		X		
Turritella ocoyana Conrad			X	
Turritella variata Conrad			X	
Triptera clavata Gabb			X	

SPECIES CONFINED TO THE UPPER MIOCENE IN CALIFORNIA—SANTA MARGARITA, JACALITOS, SAN PABLO AND ETCHEGOIN FAUNAS

GENERA AND SPECIES	Santa Margarita	Etchegoin
Astrangia coalingaensis Vaughan		X
Favia merriami Vaughan		X
Stephanocoenia fairbanksi Vaughan		X
Amphiura sanctaecrucis Arnold	X	
Asterias remondi Gabb	X	
Astrodapsis antiselli Conrad	X	
Astrodapsis tumidus Remond	X	
Astrodapsis whitneyi Remond	X	
Clypeaster bowersi Weaver		X
Clypeaster gabbi Remond	X	
Anomia subcostata Conrad		X
Arcopagia unda Conrad	X	
Cyrena californica Gabb	X	
Diplodonta harfordi Anderson	X	X
Diplodonta parilis Conrad	X	X
Dosinia jacalitosana Arnold	X	
Gari alata Gabb	X	
Glycimeris coalingaensis Arnold	X	X
Hinnites crassus Conrad	X	
Lucina estrellana Conrad	X	
Macoma jacalitosana Arnold	X	
Mactra coalingaensis Arnold		X
Meretrix uniomeris Conrad		?
Modiolus directus Dall		X
Mya japonica Jay		X
Mytilus coalingaensis Arnold	X	X
Ostrea atwoodi Gabb	X	X
Ostrea bourgeoisi Gabb	X	
Ostrea heermanni Conrad		X
Ostrea panzana Conrad	X	
Ostrea vespertina Conrad		X
Ostrea vespertina, var. *sequens* Arnold		X
Paphia jacalitosana Arnold	X	
Paphia truncata Gabb	X	
Pecten carrizoensis Arnold		X
Pecten deserti Conrad		X
Pecten eldridgei Arnold	X	
Pecten etchegoini Anderson		X
Pecten keepi Arnold		X
Pecten pabloensis Conrad	X	
Pecten veatchi Gabb	X	
Placuanomia californica Arnold	X	X
Schizodesma abscissa Gabb	X	X
Siliqua nuttalli Conrad		X
Tellina aragonia Dall	X	
Thracia jacalitosana Arnold	X	
Transenella californica Arnold		X

Species Confined to the Upper Miocene in California—Santa Margarita, Jacalitos, San Pablo and Etchegoin Faunas—*Continued*

Genera and Species	Santa Margarita	Etchegoin
Astyris richthofeni Gabb		×
Bathytoma coalingaensis Arnold		×
Calliostoma coalingaense Arnold		×
Calliostoma kerri Arnold		×
Cancellaria vespertina Anderson	×	
Goniobasis kettlemanensis Arnold		×
Littorina remondi Gabb	×	
Littorina mariana Arnold		×
Margarita johnsoni Arnold	×	
Nassa californiana, var. *coalingaensis* Arnold		×
Neptunea recurva Gabb	×	
Pisania fortis, var. *angulata* Arnold		×
Thais etchegoinensis Arnold		×
Thais kettlemanensis Arnold	×	×
Turritella vanvlecki Arnold	×	×
Trophon coalingaensis Arnold		×

List of Miocene Species that are Still Living

Genera and Species	San Lorenzo	Vaqueros	Temblor	Monterey	Santa Margarita	Etchegoin	San Diego-Purisima	Santa Barbara	Quaternary	Living
Terebratalia occidentalis Dall		×			×	×	×			×
Balanus concavus Brown		×			×	×				×
Cardium quadrigenarium Conrad			×	×	×	×	×	×	×	×
Chama pellucida Sowerby						×			×	×
Clidiophora punctata Conrad					×	×	×		×	×
Cumingia californica Conrad						×	×	×	×	×
Dosinia ponderosa Gabb			×	×	×	×	×		×	×
Glycimeris septentrionalis Midd						×			×	×
Hinnites giganteus Gray		×	×		×	×			×	×
Macoma calcarea Gmelin			×	×		×	×	×	×	×
Macoma inquinata Deshayes						×			×	×
Macoma secta Conrad			×		×	×	×	×	×	×
Macoma nasuta Conrad			×	×	×	×	×		×	×
Mactra catilliformis Conrad	×	×	×	×				×	×	×
Metis alta Conrad			×		×		×		×	×
Modiolus capax Conrad					×				×	×
Modiolus rectus Conrad					×	×	×		×	×
Monia macroschisma Deshayes					×		×	×	×	×
Mya japonica Jay						×				×

List of Miocene Species that are Still Living—*Continued*

Genera and Species	San Lorenzo	Vaqueros	Temblor	Monterey	Santa Margarita	Etchegoin	San Diego-Purisima	Santa Barbara	Quaternary	Living
Nucula castrensis Hinds					X	X	X	X	X	X
Ostrea lurida Carpenter						X	X		X	X
Leda taphria Dall			X	X			X		X	X
Panopaea generosa Gould			X	X	X	X	X	X	X	X
Paphia tenerrima Carpenter					X	X	X		X	X
Paphia staminea Carpenter							X	X	X	X
Pecten hastatus Sowerby						X	X	X	X	X
Phacoides annulatus Reeve				X	X	X	X	X	X	X
Psammobia edentula Gabb		X	X				X		X	X
Phacoides richthofeni Gabb		X	X	X			X			X
Pholadidea ovoidea Gould						X	X			X
Tellina idae Dall			X					X	X	X
Saxidomus nuttalli Conrad			X		X	X	X	X	X	X
Semele rubropicta Dall						X			X	X
Siliqua nuttalli Conrad					X		X		X	X
Solen sicarius Gould			X	X	X		X	X	X	X
Venericardia ventricosa Gould						X	X	X	X	X
Yoldia cooperi Gabb					X		X		X	X
Zirphea gabbi Tryon					X	X	X		X	X
Bathytoma carpenteriana Gabb						X	X		X	X
Bittium asperum Gabb					X			X	X	X
Crepidula onyx Sowerby					X		X		X	X
Littorina planaxis Phill					X					X
Lunatia lewisii Gould				X	X	X	X	X	X	X
Nassa californiana Conrad					X			?	?	?
Neverita recluziana Petit					X		X	X	X	X
Ocinebra lurida Midd					X		X		X	X
Olivella biplicata Sowerby					X		X	X	X	X
Olivella pedroana Conrad			X		X	X		X	X	X
Thais canaliculata Ducl					X		X		X	X
Thais crispata Chem						X	X		X	X
Trophon stuarti Smith						X		X	X	X